THOR Cloud Thickness from Offbeam Lidar Returns

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Introduction

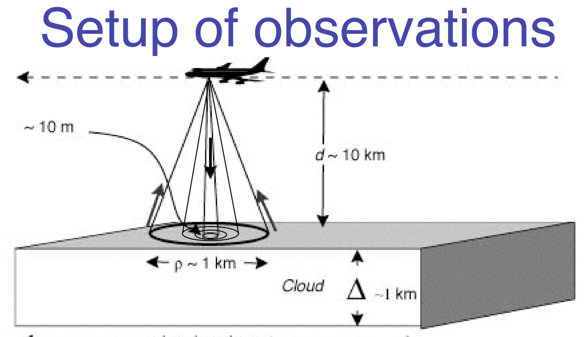
Lidar pulses penetrate clouds only up to $\tau \approx 2$, as distinct laser pulse spreads into a diffuse halo that lies outside the narrow field-of-view of conventional lidars.

New lidars built for halo observations:

THOR: on aircraft flying above clouds (NASA GSFC)
ISL: on aircraft flying inside cloud (U. of Colorado)
WAIL: on ground (LANL)

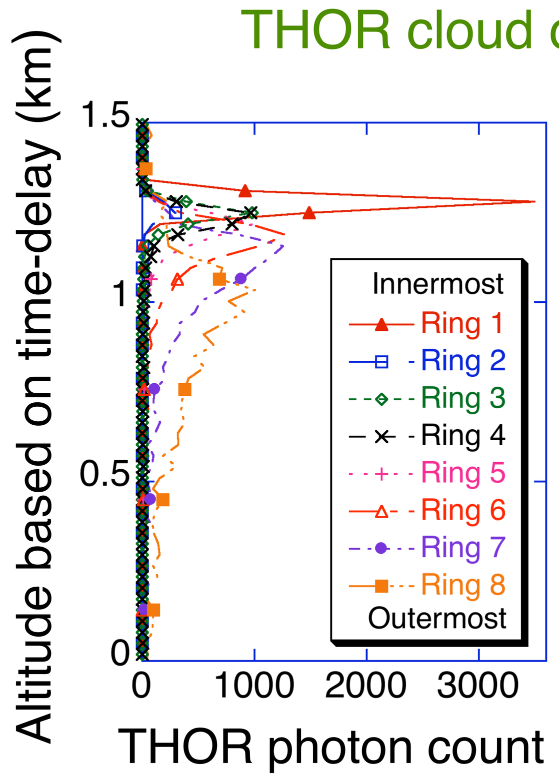
THOR instrument

Setup of observations



THOR observes direct backscatter + 7 concentric rings in halo

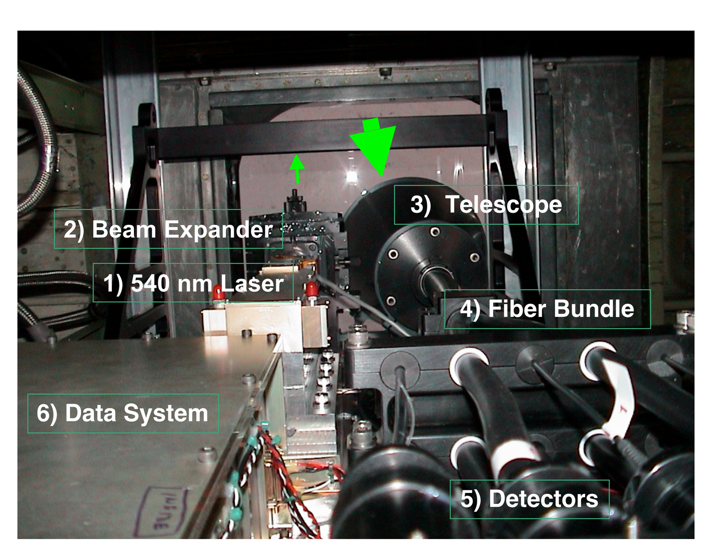
THOR cloud observations



Signal of outer rings is:

- *delayed* (photons need time to travel to outer rings)
- *spread out* (some photons meander more than others)

Photo of THOR in NASA P-3B aircraft

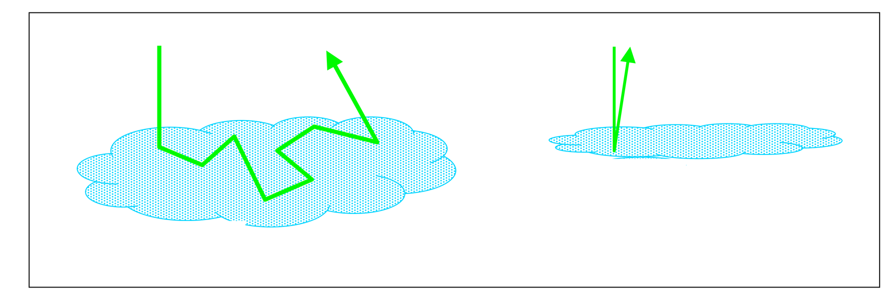


Technical specifications:

Wavelength: 540 nm
Pulse rate: 1 kHz
Pulse energy: 225 μJ
Range-resolution: 30 m

Cloud retrievals

Basic idea

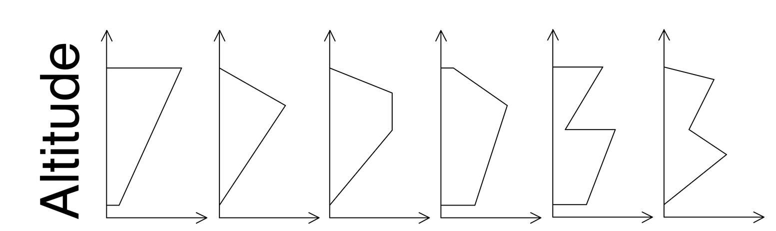


Thick cloud: large halo (photons travel far)	Thin cloud: small halo (photons escape)

Approach

Compare observations to tables created by 3D Monte Carlo radiative transfer simulations

Simulations use a variety of cloud models, and so retrievals yield information on internal structure



THOR validation campaign

ARM SGP site, March 2002

THOR on board NASA P-3B aircraft

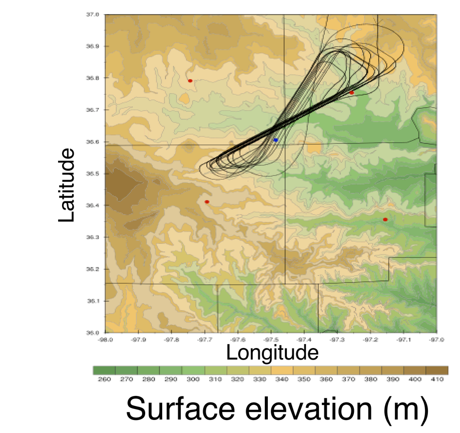
March 19: first-ever THOR flight
March 20: test flight
March 24: clear-sky flight
March 25: cloudy-sky flight

Validation of physical thickness retrievals

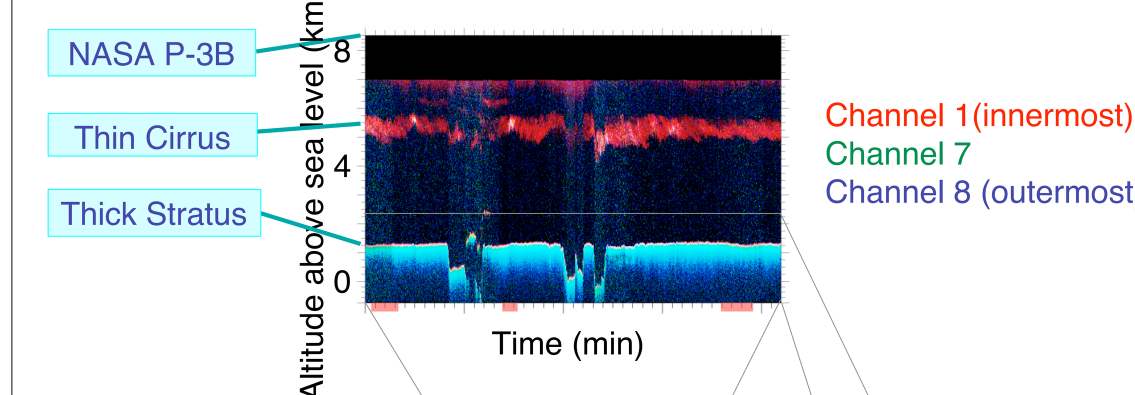
Compares THOR's halo-based cloud thicknesses to

$\Delta Z = Z_{\text{cloud top}}(\text{THOR}) - Z_{\text{cloud base}}(\text{ARM instruments})$

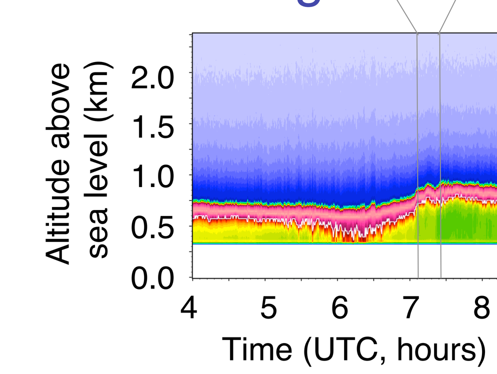
Flight path of March 25 flight



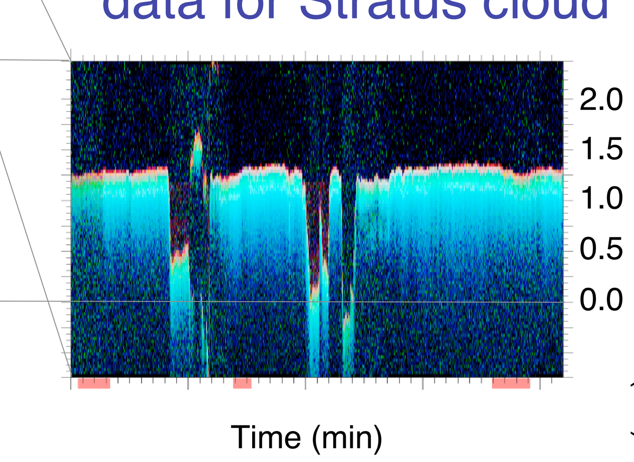
RGB composite of THOR data



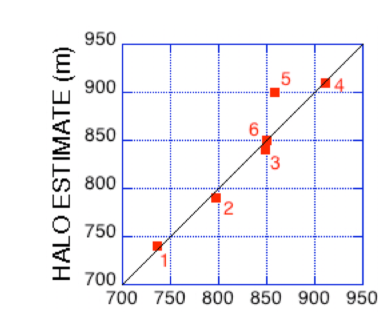
ARM Micropulse Lidar data revealing cloud base



RGB composite of THOR data for Stratus cloud



A comparison of cloud thickness values for six segments of thick stratus (seen through thin Cirrus)



Conclusions

- THOR lidar gives new information on the **physical** thickness and structure of optically thick clouds
- ARM SGP site provided excellent data for validating THOR's cloud thickness retrievals